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ABSTRACT

Background information, lists of materials needed, and detailed procedures are provided for five science projects. These projects involve constructing and using: (1) an electric pencil; (2) a buzzer to send coded messages; (3) a battery which produces light; (4) a radio that plays for free; and (5) a supersensitive cigar-box microphone. Diagrams illustrating procedures, circuits, and/or equipment are included when applicable. (JN)

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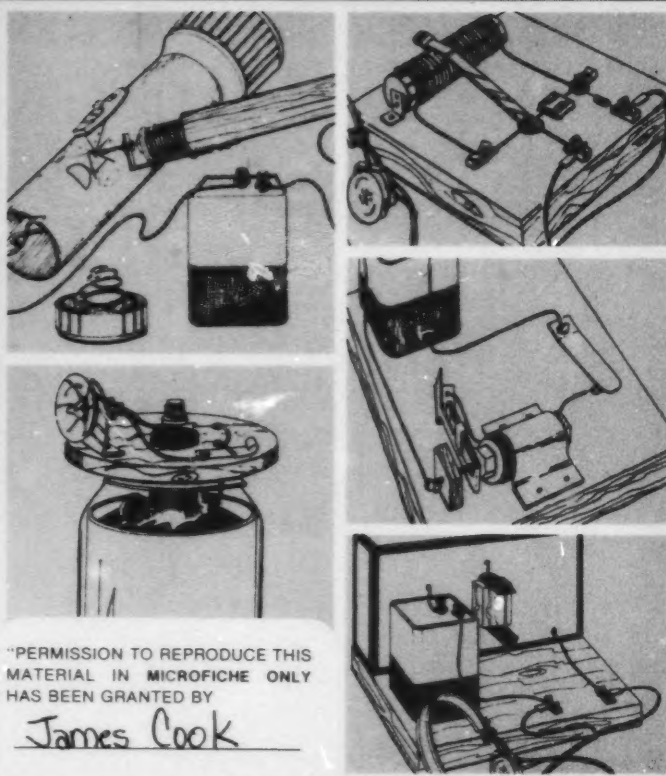
USEFUL SCIENCE PROJECTS ... from Edison

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OF THOMAS ALVA EDISON

He has led no armies into battle . . . he has conquered no countries . . . yet he wields a power the magnitude of which no warrior ever dreamed . . . this democratic, kindly, modest man has bestowed upon the human race blessings instead of bondage, service instead of serfdom, construction instead of conquest . . . he is humanity's friend.

Arthur J. Palmer

USEFUL SCIENCE PROJECTS ... from Edison

Text

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Design and Illustrations

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Publication of the

THOMAS ALVA EDISON FOUNDATION

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TO THE YOUTH OF AMERICA

Electricity . . . it's hard to believe such a force exists. Like an eternally grateful genie uncorked from the flask of time, electricity serves us in every way imaginable. It warms us, cools us, entertains us; it lights our homes, does our work, cures our ills. It literally makes the world run.

How can electricity do all these things? we ask ourselves. What is it anyway? Although technical people are able to answer such questions, they still don't know the whole story. Much remains to be learned. For a more complete picture, we look to you: the youth of today, the scientists and engineers of tomorrow.

The late Charles F. Kettering, founding father of the Thomas Alva Edison Foundation, once said, "One Thomas Edison in a generation is no longer enough." How very true. To maintain its rapid rate of progress, modern civilization needs a hundred Edisons, a thousand in fact.

But for a person to develop a technical mind, the interest in science must come early. And it must spring from within the heart. Perhaps in building the devices in this booklet, you will experience a sense of adventure and accomplishment that will enkindle this interest.

We sincerely hope so. The future of our country depends upon how technologically strong you can keep it.

Board of Trustees
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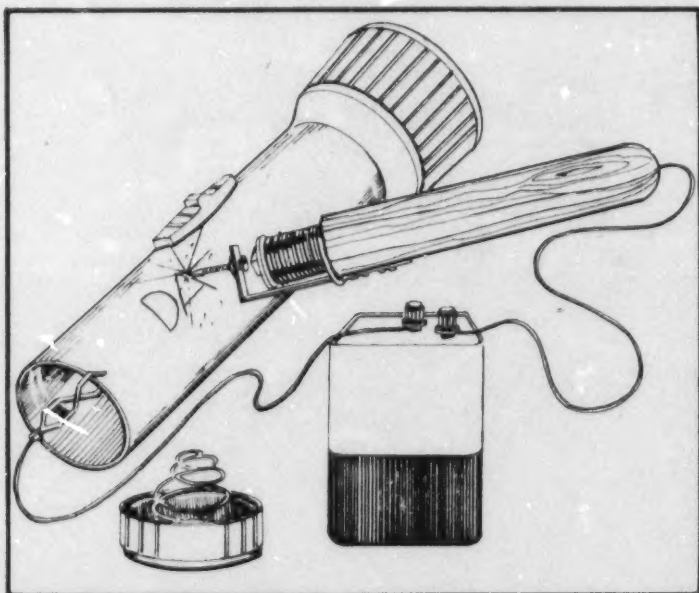
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WRITING WITH SPARKS

In 1875, Thomas Edison invented a device called the electric pen. He designed the pen for writing words — in the form of fine holes — quickly and easily on special paper. The paper thus became a stencil.

Placing the stencil on a clean sheet of paper and then running an inked roller over the stencil produced a copy of the written words. The stencil could be used about 5000 times. This early idea of Edison's gave birth to a basic office machine, his Mimeograph, that in modern form is still used today for reproducing letters and similar matter.

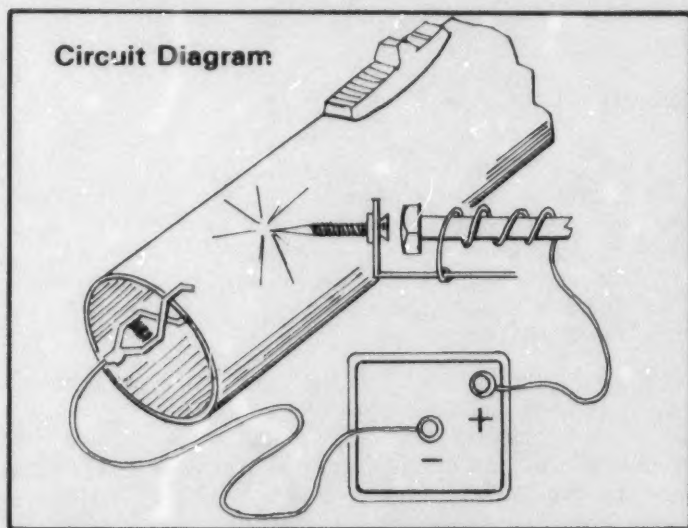
The electric pencil you are going to make is a cousin to Edison's pen. Instead of making holes in the paper, however, the electric pencil sparks a trail on metal. But being such a simple instrument, it will work only on soft metal.



How Does the Electric Pencil Work?

Our electric pencil operates on the same general principle as Edison's pen: the making and breaking of an electromagnetic circuit. As you already know, electricity flowing through a conductor causes an electromagnetic field to form around that conductor. For this priceless bit of technical knowledge, we can thank the Danish physicist Hans Christian Oersted, who made the discovery back in 1819.

BOLT BECOMES AN ELECTROMAGNET. To see how the principle of electromagnetism applies to the electric pencil, let's look at the circuit diagram. Assume the pencil tip has just touched the flashlight. This completes the circuit and allows current to flow (current is considered to flow from + to -). At that precise instant, a magnetic field builds up around the coil, making the core (iron bolt) an electromagnet. The core, as a result, attracts the tip and starts pulling it away from the flashlight. However, even though the circuit is being opened, the current tries to keep flowing. So it begins arcing from the tip.



BROKEN ARC STOPS CURRENT. When the increasing distance between tip and flashlight becomes too great for the arc to continue, the arc breaks. Immediately, the magnetic field around the coil collapses, and the core releases its electromagnetic hold on the tip. Tension on the flexed metal arm then snaps the tip back onto the flashlight. And the cycle begins all over, repeating itself many times each second.

It is the intense heat of the bluish arc that enables the pencil to "write." As the pencil moves along, the arc actually scorches the surface of the metal and thereby leaves a lasting trace.

Things You Need

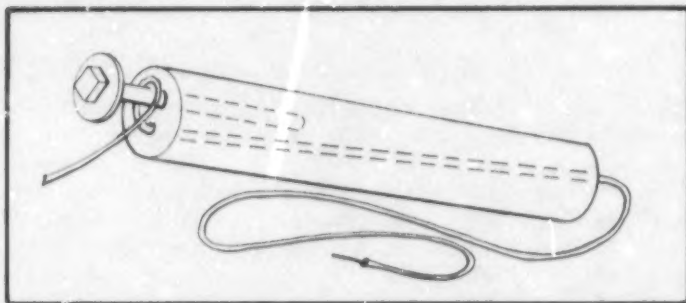
HANDLE: wood dowel, 1" by 5" (the top of an old broomstick would be perfect). **CORE:** iron bolt, 1/4" by 1-3/4". **COIL:** spool of #22 or #24 solid back-up wire. **ARM:** tin-can strip, 1/2" by 3". **TIP:** flat-head machine screw and nut, 1/8" by 3/4". **BATTERY:** 6 volts (12 volts would be even better, but not necessary). **MINOR ITEMS:** 3/4" outer-diameter washer, 2 small screws, spring clamp.

How to Make the Parts

THE HANDLE AND THE CORE. Start by rounding off one end of the wood rod, if not already round. Drill the core hole in the other end as shown in the drawing. Make it slightly less than 1/4" in diameter and about 1" deep. After slipping the washer around the iron bolt, twist the bolt into this hole. A little wax or soap on the threads will help. Leave 1" between the handle and the washer.

For a neat, professional-looking job, it would be nice to have a wire hole extending clear through the handle from the flat end to the round end. Use a 1/8" drill; bore-in half way from both ends. If you can't perform this operation, don't worry. You can run the wire along the top instead, holding it in place with tape or string.

WINDING THE COIL. Insert the hook-up wire into the hole (or run it along the top) until about 2' extend from the round end. Now begin winding the other end of the wire around the bolt. Put on as many layers as you can, finishing at the handle and trimming off all but 2" of the wire. We'll come back to the coil in a minute. But first the arm must be formed and installed.

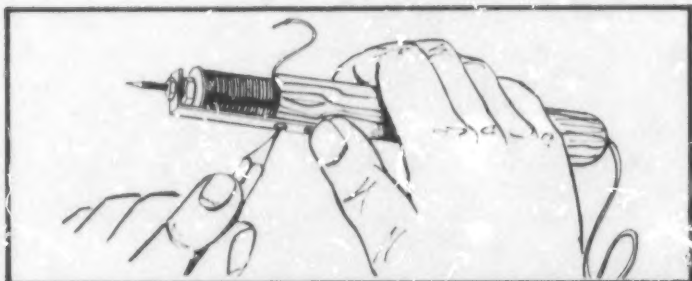


FORMING THE ARM. Fold the 1/2" by 3" tin-can strip in half, lengthwise, so that it measures 1/4" by 3". Doubling the tin-can thickness in this manner will give us the approximate flexing stiffness the arm needs. To fold the strip, simply scratch a line down the middle, clamp the strip in a vise at the line mark, and tap sideways with a hammer.

At about 1/4" from one end of the folded strip, drill a hole big enough to receive the machine screw. Then at the same end of the strip, make a 90° bend at a position such that when the long end of the arm is in place on the handle, the drilled hole will fall directly over the center of the bolt head.

Assembling the Pencil

First the machine screw must be filed to a point. Do this by placing the nut on the screw tightly, then letting the jaws of your vise grip the nut. When a long point is formed, remove the nut (this helps re-shape any roughened threads). Now insert the screw in the arm. Replace the nut and tighten.



With your thumb, press the base of the arm against the bottom of the handle, and position the arm so that about $1/32''$ clearance exists between bolt and screw. At this point, mark the screw holes. Then secure the arm to the base with the two small screws. Leave enough space under the head of one of these screws to wrap the bared end of the 2" tail from the coil. Now tighten it down. **CAUTION:** Don't use long screws. You wouldn't want a screw accidentally digging into the wire inside the handle. This would cause current to take a short cut through the screw and bypass the coil.

The Pencil in Action

To use the pencil, all you have to do is connect the pencil to the 6-volt (or 12-volt) battery and then run a line from the battery to the part, using the clamp to hold the line on.

Make sure the area to be "branded" is clean, bare metal. This means no rust, grease, paint, or clear lacquer.

When writing, use a light touch. To get the best performance you'll probably have to make slight bending adjustments to the arm to get the right clearance between bolt and screw. If the clearance is too large, the electromagnetic force won't pull the screw in. If the clearance is too small, the screw won't have enough room to vibrate properly.

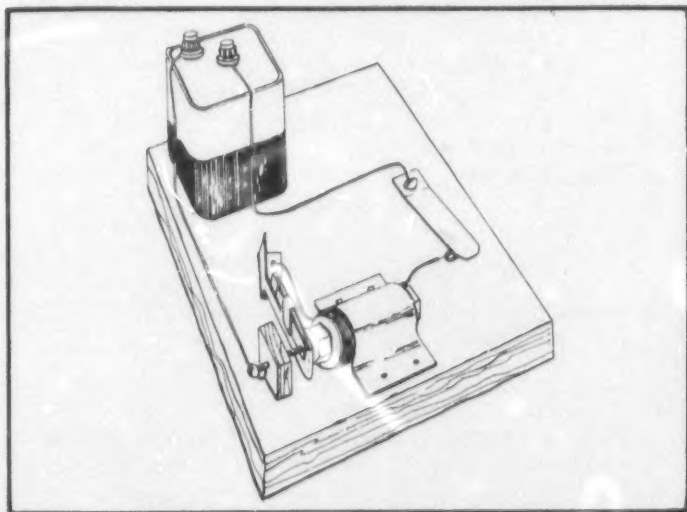
But once you're set up, the sparks should fly nicely. The inscription will be rather fine. So if you want the letters to be wider, you'll have to do some retracing.

CODED MESSAGES WITH A BUZZER

When Thomas Edison worked as a boy on the Grand Trunk Railroad in Michigan, he became familiar with the telegraph system that linked the eastern part of the U.S. with the western part. And recognizing the vital importance of this cross-country communications system, he later made many improvements to it.

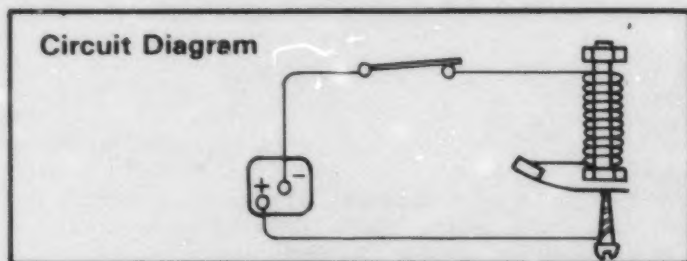
For example, he invented the duplex, the quadruplex, and the multiplex telegraph systems, which increased the number of messages that could be sent simultaneously over the line. Before those inventions, a line could handle only one message at a time and in only one direction.

Similar in principle to the initial telegraph system (and, in fact, the electric pencil) is the buzzer you are about to build. Only instead of producing a single click when the code key is depressed as did the telegraph, the buzzer gives off a continuous sound.



How the Buzzer Works

For a better understanding of the buzzer's operation, look at the circuit diagram. Imagine you've just pressed the code key down. Let's see what happens, starting at the corner terminal of the battery.



Instantly, current shoots downward to the brass contactor screw. Since the screw is touching the vibrator arm, the current continues on its way into the coil. Out of the coil it streaks past the closed code key and back to the battery.

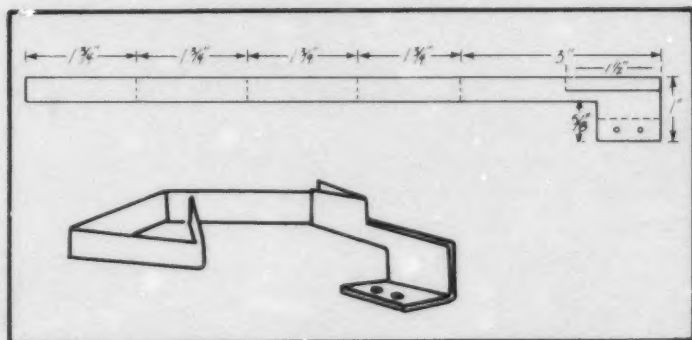
As in the electric pencil, this flow of current creates a magnetic field around the iron bolt. Having become an electromagnet, the bolt attracts the vibrator arm. But as the arm starts to swing toward the bolt, it opens the circuit. Hence, the current stops. As a result, the magnetic field collapses, allowing the vibrator arm to spring back against the contactor. With the circuit now restored, current starts flowing again . . . and the cycle starts anew.

No matter how quickly we press and release the code key, the current will still make hundreds of round trips through the circuit. And because of the resulting rapid motions of the vibrator arm, a buzzing sound is heard.

Not only is the code set fun to build, but it is even more fun to use, especially with a fellow operator. So that both of you can send as well as receive messages, you will want to build two identical sets of buzzers and code keys. They're really not hard to make. For each set you will need the following materials.

ELECTROMAGNET: bolt and nut, 5/16" by 2"; 2 washers; also the spool of hook-up wire used in the electric pencil experiment. **ELECTROMAGNET COVER:** tin-can strip, 1-1/2" by 3-1/2". **VIBRATOR ARM:** tin-can strip, 1" by 10". **SLIDER CLIP FOR VIBRATOR ARM:** tin-can strip, 3/16" by 1". **CONTACTOR:** brass screw, 1" long. **CONTACTOR HOLDER:** wood, 1" by 1" by 3/8". **CODE KEY:** tin-can strip, 1/2" by 5". **BASE:** wood, 7" by 9" by 3/4". **BATTERY:** 6 volts (12 volts would be even better). **MINOR ITEMS:** 6 or 8 small nails, 4 round head screws.

WINDING THE ELECTROMAGNET: Place a washer at each end of the bolt and engage the nut so that it just covers the end of the bolt. Starting at either end of the bolt and leaving about 6" of wire for making connections, begin coiling the wire around the bolt between the washers. Carefully wind one layer along the length of the bolt and another layer back toward the starting point. Keep doing this until several layers of wire have been put on. Plan to finish the winding at the opposite end from which you started. Cut off all but 6" of wire. Now wrap some tape around the coil to keep it from unwinding.



FORMING THE VIBRATOR ARM: Finish cutting and folding the 1" by 10" strip as shown in the drawings. Tap the folded ends with a hammer to keep the layers of metal close together. Punch two holes in the base so the arm can be mounted.

MAKING THE CONTACTOR: Since you will have to experiment to find the best spacing between contactor and bolt head, the contactor should be adjustable. That's why a screw is used. A 1" brass screw with the point filed flat makes a good contactor.

To prepare the holder, lay the 1" by 1" by 3/8" piece of wood flat; and in the exact center drill a hole slightly smaller than the screw. Drive the screw through the wood.

CUTTING OUT THE CODE KEY: Once you've snipped a 1/2" by 3" strip from the tin can, the code key is practically made. All that remains to be done is to punch a hole about 1/2" from one end so the key can be screwed to the base board. If you want a fancier key, you can attach a small wooden knob to the sending end. With a round head screw, fasten the knob to the key by screwing from the bottom up. In that way the screw head can serve as an electrical contact.

Mounting the Parts on the Base

Using the main drawing as a reference, position the parts accordingly. The electromagnet can be held down a dozen different ways. A simple, yet professional looking way requires a tin-can strip about 1-1/2" by 3-1/2". Shape the strip around the coil, and bend the ends outward so that they lie flat on the board. Punch a couple of holes in each end, then nail everything in place.

Next, locate the wooden holder for the contactor about 3/8" from the bolt head. Secure it in place either by gluing or by nailing from the bottom up.

To install the vibrator arm, proceed as follows: Line up the arm so that it is parallel with, and touching, the face of the bolt. Pound a nail part way in the hole that is nearer the bolt.

Push the rear of the arm sideways so that the arm swings away from the bolt, causing the thin strip on the other side of the arm to press firmly against the contactor screw. The thin strip and the screw must make full contact with one another. While still pressing against the rear of the arm, put a nail in the remaining hole; and pound both nails all the way in.

Finally, mount the code key, using a screw. Bend the key so that the free end is about 1/2" above the board. You will need a contacting terminal on the board directly under the free end of the key. Use a small round head screw. If you've put a knob on the key, the base screw should be directly beneath the knob screw. Be sure the contacting portion under the key is scraped clean, to the bare metal.

Hooking-Up the Circuit

This is the simplest part of the whole project. Just make the connections as indicated on the circuit diagram. In all cases, bare metal should be touching bare metal, and the connections should be tight. It would be best if you could solder the wire leading to the contactor screw. If you can't, wrap the wire around the screw and twist it with a pair of pliers. In either case, allow enough wire for the screw to be turned. For the base of the arm, lift one of the nails just enough to tie the wire around it. Then pound it back down.

Both wires to the code key should be looped clockwise around the loosened screws. After tightening the screws and connecting the battery, you are ready to try out the set.

Adjusting the Set

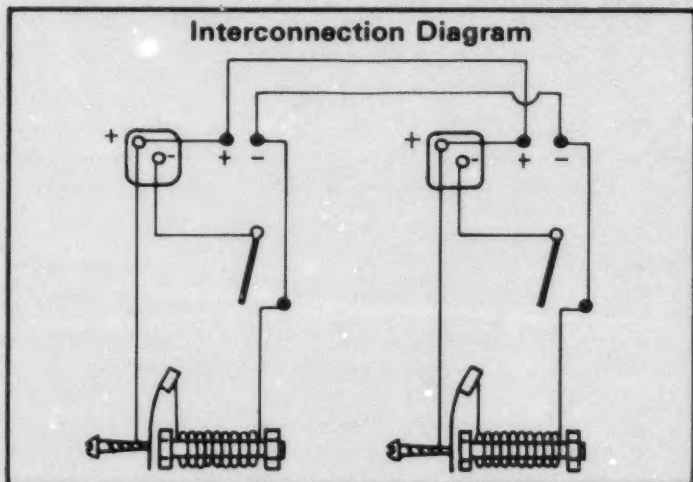
Start with a gap of about 1/8" between vibrator arm and bolt face. Tap the code key a few times. You should get some kind of response. To find the best setting, adjust the contactor screw and the spring force of the vibrator arm against the screw. You can also vary the sound of the buzz with the slider clip. Bend it in half and place it on top the vibrator arm.

NOTE: Arcing between the contactor screw and vibrator arm is normal. But it will dirty the contacts, which can in time stop the current. So, occasionally clean the screw with a file and scrape the arm with a knife.

Connecting Two Sets

As it now stands, the set can be used by itself. And it will provide hours of fun for anyone interested in learning code. But let's assume you've got a code buddy and that the two of you have made identical sets, each with its own battery. What now?

First, you will have to add two more terminals to each set (see interconnection diagram). Use screws. Add a wire from the + terminal of the battery to one screw and mark the screw +. Add another wire from the open end of the code key to the other screw and mark that screw -. Upon connecting the two sets, run one wire from + screw to + screw and the other wire from - screw to - screw. Now when you tap the code key, your set will work and so will your buddy's. And vice versa. In that way, the sender can hear what he's sending.



Using the Buzzer

How do we send coded messages with a buzzer? It's fairly easy. The buzzer is a form of doorbell, the kind that rings steadily as long as the button is held in. By depressing the buzzer's code key for a split second, we produce a short sound. And by holding the key down a trifle longer, we produce a longer sound.

These short and long sounds can be combined in different ways to represent letters of the alphabet. The Morse code, a sound language used by radio operators all over the world, tells us what combination of short and long sounds (dots and dashes) stands for each letter.

A	..	M	--	Y	..--
B	...	N	..	Z	--..
C	.-.	O	---	1	.----
D	..	P	.-.	2	..---
E	.	Q	---.	3	...--
F	..-.	R	..	4	-
G	---.	S	...	5	
H		T	-	6	-....
I	..	U	..-	7	-.....
J	.----	V	...-	8	-----
K	-.-	W	..--	9	-----
L		X		0	-----

COMMA	---.---	OVER	--
PERIOD	-.-.-	OUT	.-.-.

Actually, you can "talk" Morse code as well as send it by key. For example, in pronouncing the letter *a* (.-), an experienced radio operator would say, di dah. For the letter *b* (-...), he would say dah di di dit. Knowing the sounds of each letter in this manner helps in learning the code.

When sending a message, allow a little time between letters and more time between words. The message "good night" should go like this:

G O O D N I G H T
 --- -- -- -- --- --- -

If the sender of this message wanted a reply, he would wait a moment and tap the letter *k* (---). This is code talk for "over." In effect it means, "It's your turn to send." If the sender expected no reply, he would tap out the letters *ar* (---), without a pause between letters. This is also code for "out." And this, in effect, means, "I won't be sending or receiving any more, for now."

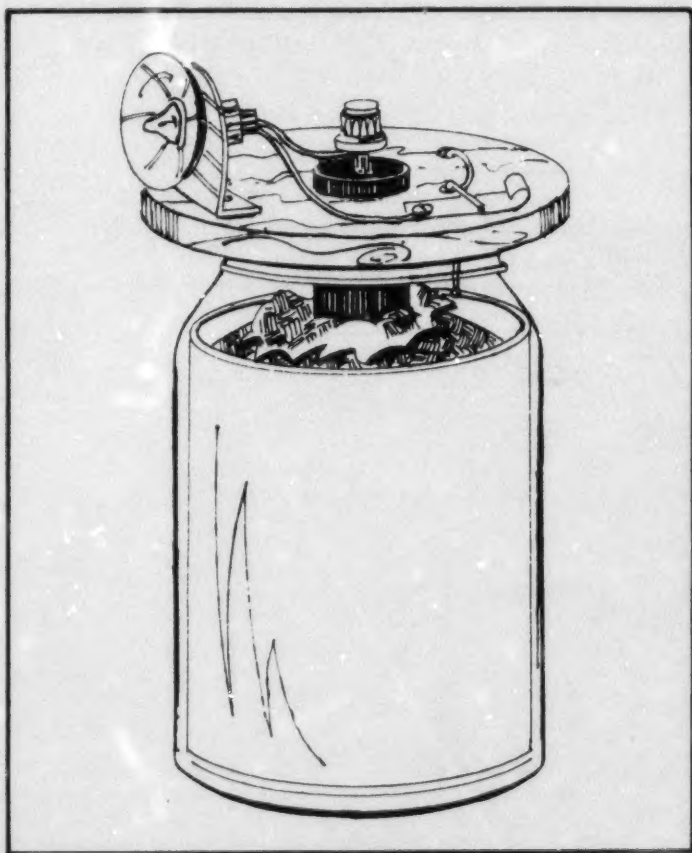
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LIGHT FROM A "FRANKENSTEIN" BATTERY

Although his greatest achievements marked him as an inventor of electrical and mechanical things, Thomas Edison always thought of himself as a chemist. "Grand science, chemistry," he said. "I like it best of all the sciences."

Without question, Edison's most outstanding invention in the field of chemistry was the nickel-iron-alkaline battery. He perfected this revolutionary battery in 1908, after 10 years of research, 50,000 experiments, and a million dollars of his own money. His relentless hunt for a good storage battery has become a famous chapter in the history of applied science. Equally remarkable, his nickel-iron-alkaline battery, although created half a century ago, is still being made and used today — this era of space probes, lasers, and nuclear power plants.

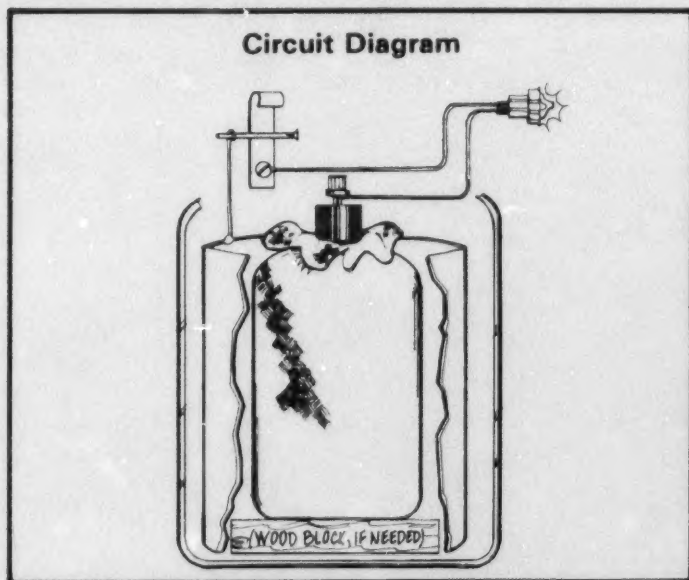
We couldn't hope to build even a crude version of Edison's battery. For one thing it requires special materials. But we can make a much simpler type of battery. By so doing, we will get a clearer picture of what a battery is and why it delivers current. Actually we're going to make a battery out of the same basic materials used in most flashlight batteries. In fact, we're going to start with the insides of a dead battery and sort of bring it back to life. This "Frankenstein" battery will even be able to do some work for us.



How Our Lamp Works

Before going any further we should point out a slight but very common mistake most of us make in using the word *battery*. The so-called flashlight battery, for example, is really not a battery. It is a cell, commonly known as a dry cell (although it does contain a moist mixture). On the other hand, the automobile storage battery is a battery. That's because it houses several cells (wet cells, in this case) connected internally. A battery, then, is a group of two or more cells, wet or dry, connected as one unit. But habits are hard to break, and we still find ourselves calling the cell a battery.

All electrical cells consist of an electrolyte (a conducting solution or paste) and two electrodes. The wet-cell lamp you're going to make uses ammonium chloride, also called sal ammoniac, as the electrolyte. Zinc is one electrode, and carbon (including the black mixture around the carbon) is the other electrode.



Look at the circuit diagram. When the lamp is operating, the zinc slowly dissolves in the electrolyte. As the dissolving goes on, an excess of electrons builds up in the zinc. Since electrons have the same electrical charge, they repel one another along the circuit. They thus force their way into the bulb filament, pass through the carbon rod, and enter the black mixture, where other reactions occur. It is this continuing movement of electrons along the circuit that we call current and that causes the high resistance filament to become white hot.

Things You Need

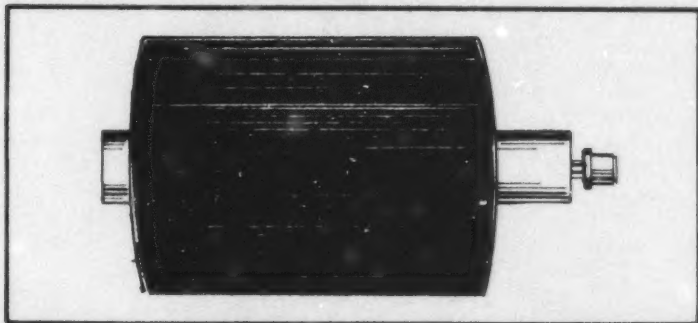
CARBON ELECTRODE: a worn-out #8 dry cell (if you plan to build the cigar-box microphone later in this booklet, try to get two dry cells while you're at it). **ZINC ELECTRODE:** zinc sheet about 5" by 10" (use whatever zinc you can salvage from the dry cell; or try galvanized sheet metal, which is zinc coated). **ELECTROLYTE:** ammonium chloride (get a small block of sal ammoniac from the hardware store; it's used for cleaning soldering iron, and is quite inexpensive). **CONTAINER:** a wide-mouthed quart jar, including lid and waxed cardboard liner. **LAMP BASE:** wood disk about 4" in diameter. **LIGHT SOURCE:** a 1-cell penlight bulb with socket. **SOCKET SUPPORT:** tin-can strip, 1" by 2". **SWITCH:** tin-can strip, 1/4" by 2". **MINOR ITEMS:** hook-up wire, aluminum foil, napkin, old nylon stocking, small nails, small screw, wax (optional).

How to Prepare the Parts

THE CARBON ELECTRODE. Let's begin by opening up the old dry cell. We should try to do it in a way that won't disturb the caked mixture around the carbon rod. Measure upward 1/2" from the bottom of the cell and draw a line around the outside. With a metal saw, make a series of cuts through the zinc casing, turning the cell slightly after each cut. When you have finished, you will be able to pull the bottom off. Then do the same thing at the top of the cell, only this time measure downward about 1-1/4". After you have cut through the casing at the top, run the saw into the mixture till you reach the car-

bon rod. A little twisting will now enable you to remove the top.

At this point, start sawing the casing lengthwise. When through the casing, spread it open . . . and there's our electrode. The black mixture should still be in one piece around the rod, and about 1" of rod should be exposed at the top. Carefully wrap a napkin or paper towel around the electrode so that it covers all the mixture. Then slip the wrapped electrode into the nylon stocking. Tie some string around the stocking above the mixture, and cut off the rest of the stocking. That takes care of the carbon electrode. (The napkin and stocking simply keep the mixture together.)



THE ZINC ELECTRODE. If you've managed to get a piece of zinc that is about 5" by 10", form it into a cylinder that just fits into the container you plan to use. The top of the zinc should be about 2" below the top of the container. Also, the zinc should have about a 6" length of copper wire soldered to it. If you don't have soldering equipment, pierce a hole in the zinc, thread the copper wire through it, and loop the wire around itself tightly.

THE ELECTROLYTE. You're probably wondering how that rock-hard sal ammoniac block is ever going to dissolve. The best way to handle this situation is to wrap the block in an old but sturdy rag. Then lay the block on cement, and break it up with a hammer. The smaller the pieces, the quicker the dissolving. Now unwrap the rag and empty the contents into

a container other than the one intended for the battery. Add a cup of warm water, stir with a stick, and set the container aside for the time being.

THE LID AND LAMP BASE. What we have to do here is form the jar lid and wood disk into one piece. So first carefully remove the waxed liner from the lid. Also remove from the center of the lid a circle of metal about 1-1/2" in diameter. This doesn't have to be done accurately or even neatly. But curled edges should be flattened with a hammer.

Next, make a 1" diameter hole in the center of the wood disk. The hole should be big enough so that the carbon rod fits easily into it. Now with the wood disk placed on something you can hammer on, center the lid on the disk and fasten with a few small nails. Pound the nails right through the lid into the disk. The nails may go through the disk, so make sure you are not working on a good surface.

Either file the protruding nail points flat, or simply bend them over. Replace the waxed liner, and cut out the 1" hole with a knife (careful now). Finally, about halfway between the inner and outer edges of the disk, drill a 1/8" hole so that the wire from the zinc electrode can be brought to the top.

You can skip the next step if you want. But ammonium chloride, as it crystallizes, may creep up the inside wall of the container or up the carbon rod and eventually work its way to the disk. To control this creeping, let the wax from a burning candle drip around the inside lip of the container and around the carbon rod (except for the part that fits into the hole in the disk).

LIGHT SOURCE AND SWITCH. For the socket support, make a 90° bend at one end of the 1" by 2" tin-can strip; and at the other end form a hole big enough to hold the socket snugly. Nail this support to the wood as shown.

Before inserting the socket, take a sheet of aluminum foil and fold it in half about three times to make it stiff. Form it into a miniature reflector, jab a hole in the center, and slip it onto the socket. Then insert the socket into the support.

The switch (the 1/4" by 2" tin-can strip) makes contact with a bent nail. Screw it to the disk wherever convenient.

Assembling the Cell-Lamp

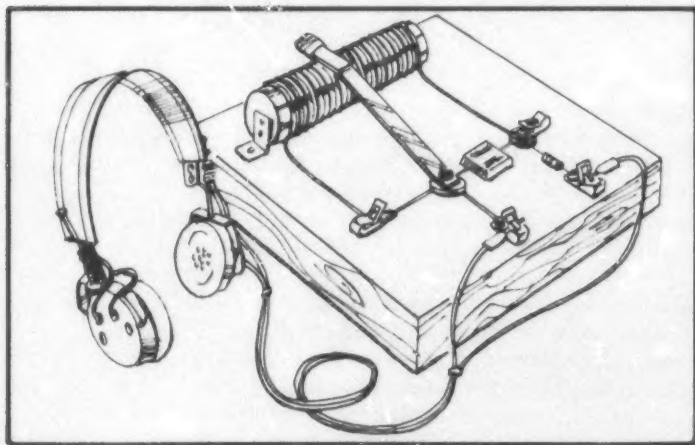
Place the carbon electrode in the container temporarily to see if the top of the carbon will be high enough. If not, you'll have to raise it by putting a block of wood on the bottom of the container. Now fill the container about half full of electrolyte. Slip the zinc cylinder over the carbon electrode and lower the two into the container. The electrolyte should cover the zinc.

Through the small hole, feed the wire from the zinc electrode. Then screw the lid on the jar firmly. Tap a small nail into the disk next to the switch. After hooking the zinc electrode wire around the base of the nail, bend the nail over so that the switch slides under it. Connect one of the socket wires to the screw on the switch; run the other socket wire to the carbon electrode terminal.

Now we're in business. Flip the switch, and our Frankenstein cell-lamp springs to life instantly. It should last for hours. If you have any trouble, try a new bulb. Or check the zinc electrode wire; it may have come off. Other than that, agitate the jar a few times or jiggle the carbon rod a little.

A RADIO THAT PLAYS FOR FREE

If someone asked you to name the man who invented radio, you wouldn't be able to answer him very easily. That's because a great many men did something important toward making the radio possible. And even though no single person deserves the most credit, certainly among the major contributors was Thomas Alva Edison.



First Electronic Tube

Edison, in fact, made the world's first electronic tube, in 1880. Scientists in those days named it the Edison-effect lamp. It consisted of an incandescent lamp into which Edison sealed a small metal plate opposite the filament. The only conducting material the plate touched was a wire leading outside the bulb to a current indicator.

Edison built this device because he was trying to learn why the insides of incandescent lamps developed a dark coating after a while. He thought maybe current existed in the space within the horseshoe-shaped carbon filament and might be carrying carbon particles to the glass. When he started experimenting he found that every time the lamp was turned on, the indicator registered a reading. The brighter the light, the higher the reading.

This meant that current was getting from the filament to the plate by traveling through space . . . in other words, *without wires* (which is what the word electronics implies). Although he didn't realize it, Edison had built the basic radio tube. His patent (no. 307, 031) on the Edison-effect lamp eventually became the cornerstone of the electronics industry.

Etheric Force: Radio Waves

But the tube wasn't Edison's only contribution to radio. He made another important discovery. This one concerned electrical energy radiation. In working with an electromagnetic vibrator (similar in principle to the common doorbell), he found that he could draw sparks from the vibrating arm by touching it with a wire. The sparks didn't behave like ordinary electrical sparks, though. For example they wouldn't charge an electroscope. After much study and experimentation, Edison concluded the sparks represented a "true unknown force." He referred to it as "etheric force." In reality, Edison had been experimenting with what are presently known as electromagnetic or radio waves. And his etheroscope (for detecting etheric force) thus became the first detector of such waves.

Now that we know a little about Edison's contributions to radio, let's turn our attention to the radio itself. One of the questions that may be popping into your mind at this point is . . .

How Does a Radio Work ?

Radio principles are not the easiest things in the world to understand. So here's a very general explanation of what is happening as you listen to your crystal radio:

Suppose the weatherman is talking. The vocal sounds he makes into the microphone at the broadcasting studio are converted into electrical signals. After going through various stages of electronic hocus pocus, the treated signals are fed into the transmitting antenna. There they are radiated in all directions as waves of a frequency belonging to that station (whose frequency is different from that of any other station in your area; otherwise you'd hear all stations at once).

As the incoming waves cut across the antenna of your crystal receiver, they induce signals of that station's frequency in the antenna. The induced signals enter the receiver, which converts them back to sounds that are almost identical to those made by the weatherman.

When we change the slider-arm position, we change the receiver's sensitivity to the frequency of the station we were listening to. At the same time, however, the moving slider arm makes the receiver sensitive to other frequencies. And we can now pick up stations broadcasting on those frequencies . . . provided, of course, these stations are in the area and transmit a fairly strong signal.

Things You Need

TUNING COIL: spool of #16 magnet wire. **CORE:** wood dowel, 1" diameter by 5". **SLIDER ARM:** stiff piece of metal about 5" by 3/8". **BASE:** wood, 8" by 8" by 3/4". **CAPACITOR:** mica capacitor, 0.002 mfd. **CRYSTAL DETECTOR:** germanium diode, IN34A. **ANTENNA:** wire, 50 to 100' long (use whatever kind you have on hand, bare or insulated . . . if bare, you'll need a glass insulator at each end of the antenna). **HEADPHONES:** a high-impedance pair of 2000 ohms (the common transistor-radio earphones may not work too well, if at all). **MINOR ITEMS:** 4 Fahnestock spring clips, 5 screws, 2 washers, 6 small nails, 2 tin-can strips 1" by 1-1/2", hook-up wire.

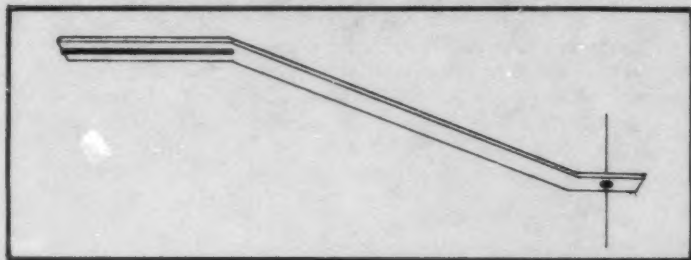
How to Build It

TUNING COIL AND CORE. If you can't find any 1" wood dowel for the core, there are other things that will work as well . . . maybe even better. A piece of 1" outer diameter rubber hose would be excellent. So would a stiff plastic tube or rod. Or, take a piece of "one by two" wood, which actually measures 3/4" by 1-1/2", and saw it lengthwise. This will give you a piece 3/4" by 3/4".

After selecting your core and cutting it to the 5" length, measure off 1/2" from each end. Then drill (or pierce) a small hole through the core at both marks. These holes will keep the magnet wire in place. Thread about 4" of wire into one of the holes, and begin winding the coil. Keep the turns close to one another. It will take about 70 turns to reach the other hole. When you reach it, thread the wire through and cut off all but 4".

Assuming you've used wood as the core, make supports for it with the 1" by 1-1/2" tin-can strips folded lengthwise for stiffness. Mount the tuning coil and core as shown in the main drawing. If you've used tubing as the core, simply lay it flat and nail it in place.

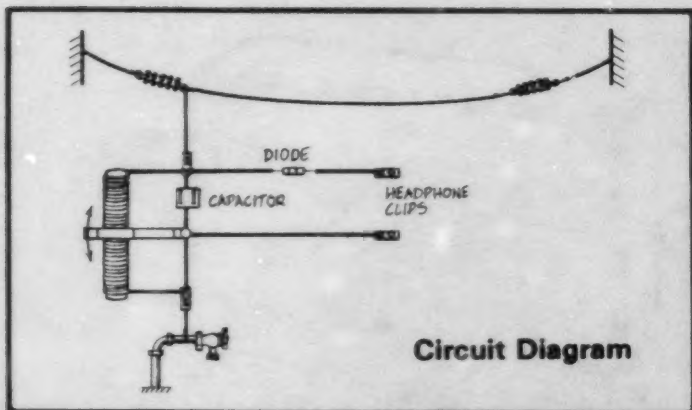
THE SLIDER ARM. Bend the 5" by 3/8" metal strip as shown in the sketch. A thick piece of bare copper wire will have to be soldered to the underside of the front. This wire allows the arm to make contact with no more than one or two turns of wire on the coil. That's important for good tuning. You can use a piece of magnet wire for this purpose if you scrape the clear insulating coating from it. Finish the slider by wrapping some tape around the front edge. The tape prevents your touching the bare metal, which could weaken the signals.



Assembling the Set

Refer once again to the main drawing, or to the circuit diagram if you prefer, and start putting the parts together. It doesn't make any difference which way you insert the capacitor. The same goes for the crystal diode. *If at all possible, make as many connections as you can by soldering.* Weak signals can be lost through poor connections.

When installing the slider, be certain the copper wire underneath touches the coil throughout the full swing of the arm. Also, take a piece of sandpaper and remove all the insulation from the top of the coil . . . right down to the bare metal. The slider must be able to make contact with each turn of wire on the coil.

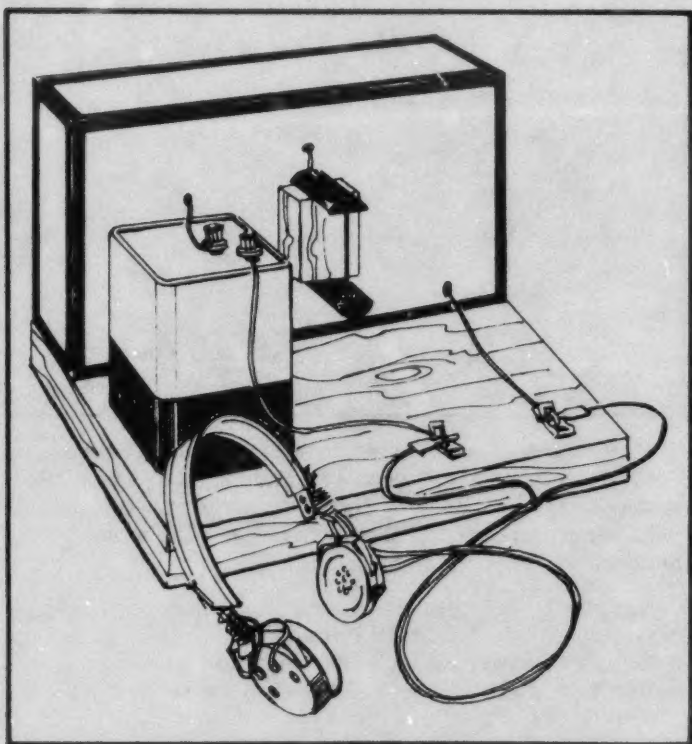


To get the most out of your crystal set, you must have a good ground connection and a good antenna. Cold-water pipes make excellent conductors to ground. Make sure the pipe has been sanded or scraped clean where you plan to make connection.

As a starter, string up a temporary antenna to see what your crystal set can do. Use about 100' of wire if you can, and locate it as high as is practical. But don't run the wire under or near power lines or leave it up when not using the set (and *never* use the set during a storm). Should you decide to erect a permanent antenna, you'd better use a lightning arrester and get some authoritative advice on installing the antenna properly.

Operating the Set

With everything assembled tightly, the ground and antenna wires connected, and headphones clipped in, we're ready for the big moment. Move the slider slowly until you pick up a station. Then adjust for loudest sound. Since the set we have built is a rather simple one, it won't receive too many stations. And it's possible more than one station will come in at the same time. But the sounds will be clear and thrilling, and the set won't cost us a penny to operate. So, happy experimenting ... and good listening.



A SUPERSENSITIVE CIGAR-BOX MICROPHONE

Although Alexander Graham Bell is credited with the invention of the telephone, it was Thomas Edison who devised the first telephone transmitter that could be used over long distances. Unlike Bell's limited-range instrument, Edison's transmitter took advantage of a wonderful property of carbon: *If a loose pack of carbon particles is squeezed, the electrical resistance of the pack decreases.* In other words when current

is passing through the pack, more current will flow when pressure is applied.

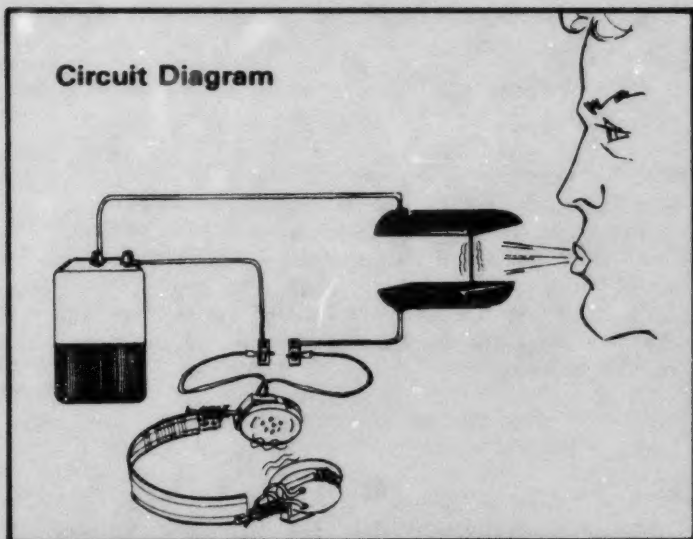
Edison had the idea that voice waves could apply that pressure. And he was right. In the carbon transmitter he perfected, loud voice sounds (upon striking the carbon particles and compressing them) caused larger currents than did quieter sounds. These variations in current traveling down a transmission line regulated a receiver at the other end of the line, and that receiver reproduced the sounds of the speaker's voice. This use of carbon in a telephone is still practiced today. Edison's carbon-particle device, then, was the forerunner of the modern telephone transmitter and the microphone used in radio broadcasting.

The cigar-box microphone, shown here, is similar to Edison's in at least one respect: It is a closed-circuit system, which means that current is constantly flowing. Edison's first "speaking telegraph transmitter" (patent no. 474,320) included this important concept. Bell's instrument did not, which is one of the reasons its range was limited to only a few miles. However, the cigar-box "mike" is not a carbon-particle transmitter, even though it uses carbon. It is a loose-contact mike. It won't give anywhere near the sound quality that Edison's did. Nevertheless, it is an extremely sensitive detector of sound and one that can be fun to make and experiment with.

How Does Our Mike Work ?

Being a loose-contact detector, the cigar-box microphone has the same high sensitivity to vibrations as insecure electrical connections. You've no doubt noticed how easily a loose light bulb flickers when someone passes by. So it is with our mike (see circuit diagram). The carbon electrodes loosely support the pencil-lead rod. The slightest vibration, like from a sound, will disturb the rod. When the circuit is closed and current is flowing through the headphones, this disturbance changes the current flow. The headphones respond to these changes and, hence, tend to imitate the sound.

Circuit Diagram



Things You Need

CARBON ELECTRODE: the carbon electrode from an old #6 dry cell. **CARBON ROD:** 1" length of lead from a wooden pencil. **ELECTRODE BASE:** wood, 2" long by 1/4" thick (width doesn't matter). **SOUNDING BOARD:** cigar box (cover not needed). **MIKE BASE:** wood, 1" by 1" by 1/4". **BATTERY:** 6 volts. **HEADPHONES:** the same ones used for the crystal radio experiment. **MINOR ITEMS:** 2 screws, 4 nails, 2 Fahnestock spring clips, hook-up wire.

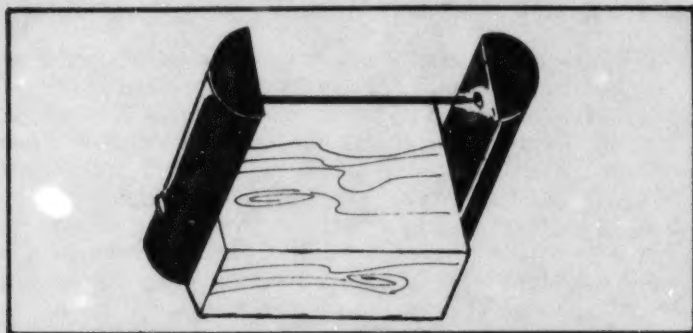
How to Prepare the Parts

FORMING THE ELECTRODES. Start by removing the 1" diameter carbon electrode from the dry cell. Bust it open with a hammer and chisel. Clean the bottom of the electrode, and saw off a 1-1/2" segment. Then saw the segment in half lengthwise, giving us two half-cylinder electrodes. You might want to file or sand the rough surfaces a bit.

To screw the electrodes to the wood base, which is $3/4$ " thick, we'll have to drill a hole in each electrode about $3/8$ " from one of the ends. Next we'll have to make two small depressions for the pencil lead to rest in. Do this by drilling a dimple in each electrode about $1/4$ " from the end opposite the screw hole.

THE LOOSE-CONTACT ASSEMBLY. Lay the wood base on a flat surface, and stand the electrodes at the ends, directly facing one another. Then secure the electrodes to the base with screws. These screws will also serve as wire contacts.

Now we come to the tricky part. The pencil lead must fit between the tightened electrodes so that it is free to move slightly. If it is held firm, our loose-contact microphone won't have a loose contact . . . consequently, it won't work. At the same time, the fit shouldn't be sloppy either. So do the best you can. But before you install the pencil lead, be sure to sharpen both ends on a file or fine sandpaper.



Putting the Microphone Together

Position the loose-contact assembly on the cigar-box as shown in the main drawing. Fasten the assembly to the box with two screws coming from inside the box. Also fasten the cigar-box to the base as shown, using the four nails. The back end of the box should extend slightly beyond the edge of the base.

The Fahnestock clips, which accomodate headphones with separated terminals, may be installed wherever you like. Possibly your headphone set (or single headphone) has a phone-plug connector. In that event you'll have to obtain a suitable receptacle.

With a pointed tool, jab four holes in the cigar-box, as illustrated, to pass wires through. This operation isn't necessary, as you can see, since the microphone can be completely wired at the front of the box. But it does result in a neater-looking job. Assuming you've made the holes, run a wire from the upper electrode screw into the box and then back out of the box to the center terminal of the battery. Do the same at the lower electrode, except run the wire to the screw on the outer Fahnestock clip. Conclude the hookup by linking the inner clip to the corner battery terminal. Now let's put our workmanship to the test and see how well the mike operates.

Using the Mike

Connecting your headphones to the microphone completes the circuit and turns the mike on. You'll be amazed at the new world of sound opened up to you. You should be able to hear your own breath blown against the pencil lead. Grains of salt dropped on the electrodes should sound like rocks; tapping the box with your fingernail might pass for a mild explosion. Try placing a spring-wound alarm clock or wrist watch on the box. Also lean a transistor radio against the box; even with the volume set low, you'll be able to hear the program through the headphones. The radio experiment will be even more impressive if you can put the mike in one room and the headphones in another.

What else can we do with the mike? Well, how about using a sewing needle instead of the pencil lead? Try it with the point down, then with the point up; turn it to find spots of higher sensitivity. Lay the box flat. Hold it against a wall and have someone talk on the other side of the wall. Also, see what happens when you adjust the electrodes, change pencil-lead hardness, or substitute a flashlight battery for the 6-volt battery.

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